CLAIMS

1. A method for determining a finite impulse response time domain equalization filter for shortening a channel impulse response in an asymmetric, dual rate data transmission system, the transmission system characterized by a transmitted signal x_k having an original channel impulse response h_k, which effectively combines with a disturbance vector v_k to result in a TEQ filter inpur signal, y_k, the method comprising the steps of:

sampling y_k;

applying a delay channel (d), which is based at least in part on transmitted signal x_k, with a target channel vector **b**, which is constrained so as to avoid an all-zeros solution; and

calculating a vector $\boldsymbol{w}^T$; so as to minimize the error, e_k, between a shortened channel impulse response, z_k, and the target channel impulse response.

2. The method of claim 1, wherein y_k has an overall effective length N_C and an effective delay channel (d).

3. The method of claim 2, wherein the effective delay channel d corresponds to the starting location of the non-zero segment of the channel impulse response.

4. The method of claim 1, wherein z_k has a channel length of N_{TEQ} that is modeled to match desired target channel length N_T of the target channel impulse response.

5. The method of claim 1, wherein h_k comprises one or more replicates of a received data set $\{x_k; k \in Z\}$.

6. The method of claim 1, wherein x_k is a received signal in a communications system.

7. The method of claim 6, wherein the said communications system is a Discrete Multitone (DMT) communications system.

8. The method of claim 1, further comprising the step of modeling w_k such that the number of bits loaded per symbol, B, is maximized.

9. The method of claim 1, wherein the vector $\boldsymbol{w}^T$ is calculated using filter coefficients $\{w_k; k \in \{1 \ \ldots \ N_{TEQ}\}\}$ as:

$$w^T = \overline{h}\left(R_v / \sigma_x^2 + H(I - F^T F) H^T\right)^{-1}.$$

where:

$\overline{\mathrm{h}}$ is a function of the impulse response coefficient;

R_V is a noise autocorrelation function;

σ_x^2 is the variance of x_k;

H is a function of the channel impulse response;

I is a function of the energy of the Inter-Symbol Interference (ISI) and the Inter-Channel Interference (ICI);

F is an intermediate variable; and

$$W \underline{\underline{\Delta}} \left[w_1 \ \ldots \ w_{N_{TEQ}} \right]^T.$$

10. The method of claim 9, wherein the filter coefficients w_k are TEQ filter length (N_{TEQ}).

11. The method of claim 10, wherein N_{TEQ} is predetermined.

12. The method of claim 9, further comprising the step of calculating F as:

$$F=\begin{bmatrix} O_{L,d} & I_{L,L} & O_{L,1} & O_{L,NT-L-1} & O_{L,NC+NTEQ-NT-d-1} \\ O_{NT-L-1,d} & O_{NT-L-1,L} & O_{NT-L-1,1} & I_{NT-L-1,NT-L-1,} & O_{NT-L-1,NC+NTEQ-NT-d-1} \end{bmatrix}$$

13. The method of claim 9, further comprising the step of calculating Rv as:

$$R_{vNTEQ,NTEQ} = \begin{bmatrix} r_v(0) & r_v(1) & \cdots & r_v(N_{TEQ}-1) \\ r_v(1) & r_v(0) & \ddots & r_v(N_{TEQ}-2) \\ \ddots & \ddots & \ddots & \ddots \\ r_v(N_{TEQ}-1) & r_v(N_{TEQ}-2) & \cdots & r_v(0) \end{bmatrix}$$

14. The method of claim 9, further comprising the step of calculating H as:

$$H = \begin{bmatrix} h_0 & h_1 & \cdots & \cdots & \cdots & h_{N_C-1} & 0 & \cdots & 0 \\ 0 & h_0 & \cdots & \cdots & \cdots & h_{N_C-2} & h_{N_C-1} & \cdots & 0 \\ \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \\ \cdots & \cdots & 0 & h_0 & \cdots & \ddots & \cdots & \cdots & h_{N_C-1} \end{bmatrix}$$

15. The method of claim 9, further comprising the step of calculating $\bar{h}$ for $d+L \geq N_{TEQ}$ as:

$$\bar{h} = \begin{bmatrix} h_{d+L} & \cdots & h_0 & 0_{1,N_{TEQ}-d-L-1} \end{bmatrix}$$

16. The method of claim 9, further comprising the step of calculating $\overline{\mathrm{h}}$ for $d+L < N_{TEQ}$ as:

$$\overline{\mathrm{h}} = \begin{bmatrix} h_{d+L} & \cdots & h_{d+L-N_{TEQ}-1} \end{bmatrix}$$

17. The method of claim 1 wherein the filter coefficients w_k are calculated using a Minimum Mean Square Error Linearly Constrained TEQ (MLC-TEQ) algorithm.

18. The method of claim 1 wherein the channel impulse response is converted into an impulse response that has effectively N_P nonzero entities.

19. The method of claim 18, further comprising the step of modeling said nonzero entities with the target impulse response coefficients sequence $\{b_k;\ k \in \{0 \ldots N_P-1\}\}$.

20. The method of claim 19, further comprising the step of formulating the target channel, t_n, as:

$$t_n = \begin{Bmatrix} b_{n-d} & d \le n \le d + N_P - 1 \\ 0 & otherwise, \end{Bmatrix}$$

where d is the effective delay corresponding to the starting location of the non-zero segment of the impulse response.

21. The method of claim 1, further comprising the step of constraining any one element of the **b** vector to be equal to a constant.

22. The method of claim 1, further comprising the step of calculating an error e_k.

23. The method of claim 22, wherein said error is calculated using the difference between the TEQ filter output and the TIR output.

24. The method of claim 23, further comprising the step of calculating the Mean Square of the Error (MSE), $E(e_k^2)$.

25. The method of claim 24, wherein Mean Square Error (MSE) is minimized.

26. The method of claim 1, wherein the TEQ filter coefficients are computed by minimizing the Mean Square Error (MSE) criterion.

27. The method of claim 1, wherein the TEQ filter coefficients are parameterized by two quantities.

28. The method of claim 27, wherein the the two quantities are:

the location (L) of the constrained element of the TIR vector; and

the delay value (d) used in the computation.

29. The method of claim 28, wherein the location of the constrained element of the TIR vector, L , is:

$L \in \{0,\ldots,N_P\text{-}1\}$.

30. The method of claim 28, wherein the said delay value, d, is:

$d \in \{0,\ldots,N_C+N_T\text{-}N_P\text{-}2\}$.

31. The method of claim 1, further comprising the step of modeling, by a linear time invariant system with the impulse response of the h channel, $\{h_i;i\in\{0,\ldots,N_C\text{-}1\}\}$, the combined effects of transmit filter shaping, receiver filter effects, and distortion effects caused by the transmission channel.

32. The method of claim 31, further comprising the step of choosing w_k such that the number of bits loaded per symbol, B, is maximized.

33. The method of claim 32, wherein:

$$B(\mathbf{w}) = \sum_{i \in T} \log_2 \left\{ 1 + \frac{S_i(\mathbf{w})}{(I_i(\mathbf{w}) + N_i(\mathbf{w}))\Gamma} \right\}$$

where T is the set of transmit tones,

S_i(w) is the desired signal energy at tone i,

I_i(w) is the combined energy of ISI and ICI at tone i caused by the components of t_n outside $d \leq n \leq d+N_P-1$,

N_i(w) is the noise energy at tone I, and

Γ is the effective gap which is a function of the constellation, coding gain, and the margin requirement.

34. The method of claim 28, wherein the location of the constrained element of the TIR vector, L, is:

$L \in \{0,\ldots,N_P-1\}$.

35. The method of claim 34, wherein:

$$L = \left\lceil \frac{N_P}{2} \right\rceil$$

36. The method of claim 35, wherein L is chosen as the center of the range of possible values that L can take.

37. The method of claim 36, further comprising the step calculating TEQ coefficients $\{w_k\}$ and target impulse response coefficients $\{b_k;\ k \in \{0,\ldots,N_P-1\}\}$.

38. The method of claim 36, further comprising the step of imposing a constraint, $b_L = c$, on b, where:

$L \in \{0\ldots N_P-1\}$,

$c \in \Re$, and

$c \neq 0$.

39. The method of claim 38, wherein $c = 1$.

40. The method of claim 1, further comprising the step of minimizing an error sequence, $\{e_k\}$, between h and d.

41. The method of claim 40, further comprising the step of minimizing the mean square of error $\{e_k\}$.

42. The method of claim 1, wherein the target channel is designed to be:

$$t_n = \begin{Bmatrix} b_{n-d} & d \leq n \leq d + N_P - 1 \\ 0 & otherwise, \end{Bmatrix}$$

where d is the effective delay corresponding to the starting location of the non-zero segment of the impulse response.

43. A data channel receiving device having a TEQ filter for filtering a data set $\{y_k; k \in Z\}$, the TEQ filter comprising:

means for sampling y_k;

means for modeling a target channel impulse response, b_k, based at least in part on applying a delay channel (d) with a target vector **b**; and

means for deriving TEQ coefficients $\{w_k\}$ by minimizing the error, e_k, between a shortened channel impulse response, z_k, and the target channel impulse response.

44. The device of claim 43, wherein the shortened channel impulse response, z_k, is derived at least in part by calculating a vector w^T.

45. The device of claim 43, wherein the TEQ filter is part of a modem.

46. The device of claim 43, wherein the transmitted signal, x_k, received by the TEQ filter through the channel h and distorted by the disturbance vector, v_k, originates from a modem device.

47. The device of claim 43, wherein the target vector **b** is constrained to avoid an all-zeroes solution.